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First description of females, juveniles and subadults of the São Francisco Sparrow, *Arremon franciscanus*, with notes on its systematic position

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The São Francisco Sparrow, *Arremon franciscanus* Raposo, 1997 (Passeriformes: Passerellidae), is a restricted range species endemic to the Caatinga of northeastern Brazil. This species has been only recently described and is known by only eight specimens deposited in three Brazilian ornithological collections: five in the type series (in the Museu Nacional / Universidade Federal do Rio de Janeiro - MN) and three additional specimens (two in the ornithological collection of the Departamento de Zoologia da Universidade Federal de Minas Gerais - DZUFMG; and one in the Museu de Zoologia da Universidade de São Paulo - MZUSP) (Raposo 1997, D'Angelo Neto & Vasconcelos 2003, Kirwan *et al*. 2004, Vasconcelos *et al.* 2006). Of the eight specimens seven are males and one is unsexed.

Figure 1. Type-series of São Francisco Sparrow *Arremon franciscanus* and additional male specimen held at Museu Nacional / UFRJ. From top to bottom: MN-43037 (holotype), MN-43040 (paratype), MN-43038 (paratype), MN-43039 (paratype), MN-39520 (paratype), and MN-47712. Photo: Nelson Buainain Neto.

Based on plumage characters in the original species' description, Raposo (1997) suggested that the Half-collared Sparrow *Arremon semitorquatus* would be the closest related species to *A. franciscanus*. He also pointed out that the still unknown female plumage of *A. franciscanus* could serve as an important feature for discussing the systematic position of this species. In recent fieldwork, we obtained 16 additional specimens of *A. franciscanus*: six females and 10 males; three of them are subadults and two are juveniles. The aim of this paper is to describe the plumage, morphometrics, and soft parts colors of females, juveniles and subadults of *A. franciscanus*, as well as to discuss how this information impacts what we know about the species' systematic position.

New specimens were collected in the following localities: Brejinho das Ametistas (14º16'S-14º20'S, 42º30'W-42º33'W; elevation 825-980 m), Caetité municipality, Bahia

Figure 2. Adult female (top) and adult male (below) of São Francisco Sparrow *Arremon franciscanus*. Plate: Vitor Torga Lombardi.

Figure 3. From top to bottom: adult female (MCNA-3591) and adult male (MCNA-3590) of São Francisco Sparrow *Arremon franciscanus* in ventral (A) and lateral (B) views. Photos: Marcelo Ferreira de Vasconcelos.

state, Brazil; Serra do Salto (14º18'S, 42º31'W; elevation 925 m), Caetité municipality, Bahia state, Brazil; Águas Vermelhas (15º41'S, 41º43'W; elevation 815 m), Águas Vermelhas municipality, Minas Gerais state, Brazil; and the surroundings of Riacho dos Machados (16º03'S-16º04'S, 43º07'W-43º08'W; elevation 805-900 m), Riacho dos Machados municipality, Minas Gerais state, Brazil. Specimens from Brejinho das Ametistas have been deposited in DZUFMG under the numbers: DZUFMG-6135, 6140, 6141, 6554 (females) and DZUFMG-6134, 6142, 6569 (males). The single male specimen obtained at Serra do Salto was deposited in MN (MN-47712). Specimens from Águas Vermelhas and Riacho dos Machados were deposited in the ornithological collection of the Museu de Ciências Naturais da Pontifícia Universidade Católica de Minas Gerais (MCNA) under the numbers: MCNA-2761, 3591 (females) and MCNA-1575, 2001, 2758, 2759, 2760, 3590 (males). We used these newly collected specimens, the type-series deposited in MN (Raposo 1997 - Figure 1), and three other adult males previously collected in Minas Gerais (DZUFMG-2480, 3382; MZUSP-76180) for comparing plumage features and measurements among sexes and ages (Table 1). Thus, our analyses were based on the entire series of *A. franciscanus* known in all collections of the world, represented by 24 specimens (Table 1).

Plumage descriptions were based on Munsell Soil Color Charts (1975, 2000). External topographic anatomy nomenclature follows Meyer de Schauensee (1982), Clark (1993) and Sick (1997). Measurements were taken using electronic digital callipers. Measurements taken were (following Baldwin *et al*. 1931, Sick 1997): total length (with feathers), length of total culmen, length of bill from nostril, height of bill at nostrils, width of bill at nostrils, length of closed wing (unflattened), length of tail (central rectrices), and length of tarsus (tarso-metatarsus). Specimens were also weighed just after collecting, using spring scales (Pesola®).

Description of adult females

A detailed description of adult females' plumage is presented below, based on DZUFMG-6135, 6140, 6554 and MCNA-2761, 3591:

Facial mask black (10YR 2/1), including forehead, lores, auriculars, and malar region. A very pale brown (10YR 8/2) (DZUFMG-6135, 6140, 6554) or white (10YR 8/1) (MCNA-2761, 3591) superciliary separates this mask of the black (10YR 2/1) sides of crown. Pileum olive gray (5Y 4/2) (DZUFMG-6135, 6140, 6554), gray (5Y 5/1) (MCNA-2761), or light gray (5Y 7/1) becoming gray (5Y 6/1) in the distal part (MCNA-3591). Nape and sides of neck olive gray (5Y 4/2). Chin black (10YR 2/1). Upperparts olive (5Y 4/4), including scapulars, mantle, rump, and uppertail coverts. Bend of wing yellow (5Y 8/6). Underwing-coverts yellow (5Y 8/6) (DZUFMG-6135, 6140, 6554; MCNA-2761) or pale yellow (5Y 8/4) (MCNA-3591). Lesser upperwing-coverts olive (5Y 4/4) with yellow (5Y 7/8) edges. Median upperwing-coverts with dark olive gray (5Y 3/2) proximal webs and olive (5Y 4/4) distal webs. Remiges dark olive gray (5Y 3/2), with olive (5Y 4/4) edges on distal web and gray (5Y 6/1) edges on proximal webs. Alula olive (5Y 4/4). Dorsal view of rectrices dark olive gray (5Y 3/2) with dark olive (5Y 4/3) edges; ventral view of the same feathers very dark gray (5Y 3/1). Throat, breast, and undertail coverts pale yellow (2.5Y 8/4). Central belly white (10YR 8/1). Interrupted pectoral band black (10YR 2/1) washed pale yellow (2.5Y 8/4). Flanks, sides of the body and thighs grayish brown (10YR 5/2).

The overall aspect of adult females' plumage is very similar to that of adult males. The most striking differences are their pale yellow (2.5Y 8/4) underparts on throat, breast, and undertail coverts that are white (5Y 8/1) in males (Figures 2-3). Other characters in which males differ from females include: a wider and brighter pectoral band pure black (10YR 2/1), never washed pale yellow; flanks, sides of the body and thighs gray (5Y 6/1) (Figures 2-3).

Description of juvenile males

Juveniles' plumage description is based on MCNA-2758 and 2759 (Figure 4), as follows:

Facial mask black (10YR 2/1) inconspicuously washed dark olive (5Y 4/3). Forehead, lores, auriculars, and ma-

lar region black (10YR 2/1). Superciliary pale yellow (5Y 8/3.5). Sides of crown grayish olive (5Y 5/3) densely barred black (10YR 2/1). Pileum olive grayish (5Y 5/3) finely barred black (10YR 2/1). Chin black (10YR 2/1). Upperparts (scapulars, mantle, rump, and uppertail coverts) dark olive (5Y 4/3) with inconspicuous black (10YR 2/1) bars. Bend of wing and underwing-coverts pale yellow (5Y 8/3.5). Lesser upperwing-coverts dark olive (5Y 4/3) with olive (5Y 5/4) edges. Median upperwing-coverts with dark olive gray (5Y 3/2) proximal webs and olive (5Y 5/4) distal webs. Remiges dark olive gray (5Y 3/2), with dark olive (5Y 4/3) edges on distal web and light gray (5Y 7/1) edges on proximal webs. Alula very dark gray (5Y 3/1). Dorsal view of rectrices dark olive gray (5Y 3/2) with dark olive (5Y 4/3) edges; ventral view of the same feathers very dark gray (5Y 3/1). Throat pale yellow (5Y 8/4). Breast pale yellow (5Y 8/4) spotted black (10YR 2/1). Sides of breast and flanks pale yellow (5Y 8/4) striped dark gray (5Y 4/1). Central belly and undertail coverts pale yellow (5Y 8/3.5). Inconspicuous black (10YR 2/1) interrupted pectoral band suffused with dark olive (5Y 4/3). Thighs dark olive (5Y 4/3).

Description of subadult males

A subadult male (MCNA-1575) has overall plumage pattern very similar to females, including pale yellow (2.5Y 8/4) on throat, breast, and undertail coverts. Nevertheless, its pileum is predominantly olive (5Y 4/4) washed gray (5Y 5/1) (Figure 5A) and its facial mask and inconspicuous interrupted pectoral band are black (10YR 2/1) suffused with dark olive (5Y 4/3), especially in the auriculars (Figure 5B).

Another subadut male (DZUFMG-6134), probably in a more developed stage, is similar to adult males, but it has a less conspicuous interrupted pectoral collar black (10YR 2/1); underparts white (5Y 8/1), similar to adult males, but washed pale yellow (2.5Y 8/4); posterior flanks olive (5Y 4/4); thighs brown (10YR 5/3).

Description of subadult female

The only subadult female (DZUFMG-6141) presents a less conspicuous interrupted pectoral band very dark gray (5Y 3/1) washed pale yellow (2.5Y 8/4). Forehead black (10YR 2/1) spotted very pale brown (10YR 8/2) and olive gray (5Y 4/2). The rest of the plumage is similar to that of adult females.

Age and skull ossification

Specimens of both sexes of *A. franciscanus* with skull ossification between 25% and 100% present typical adult plumage. Subadult males and female had skull ossification between 10% and 25%. The two juveniles had skull ossification of 10% (Table 1).

Measurements and mass

Despite the fact that we analyzed the entire series of *A. franciscanus* available in all world collections, the number of specimens analyzed is still too small to understand ontogenetic and sexual variation of measurements, and there is a large overlap in morphometric data among sexes and age classes (Table 2). Nevertheless, adult males appear tend to present longer measurements of height of bill, length of bill from nostril, length of total culmen, length of closed wing, and length of tail (Table 2). Measurements taken from juveniles and subadults are within the range of adults, but juveniles' lengths of bill from nostril are shorter (Table 2).

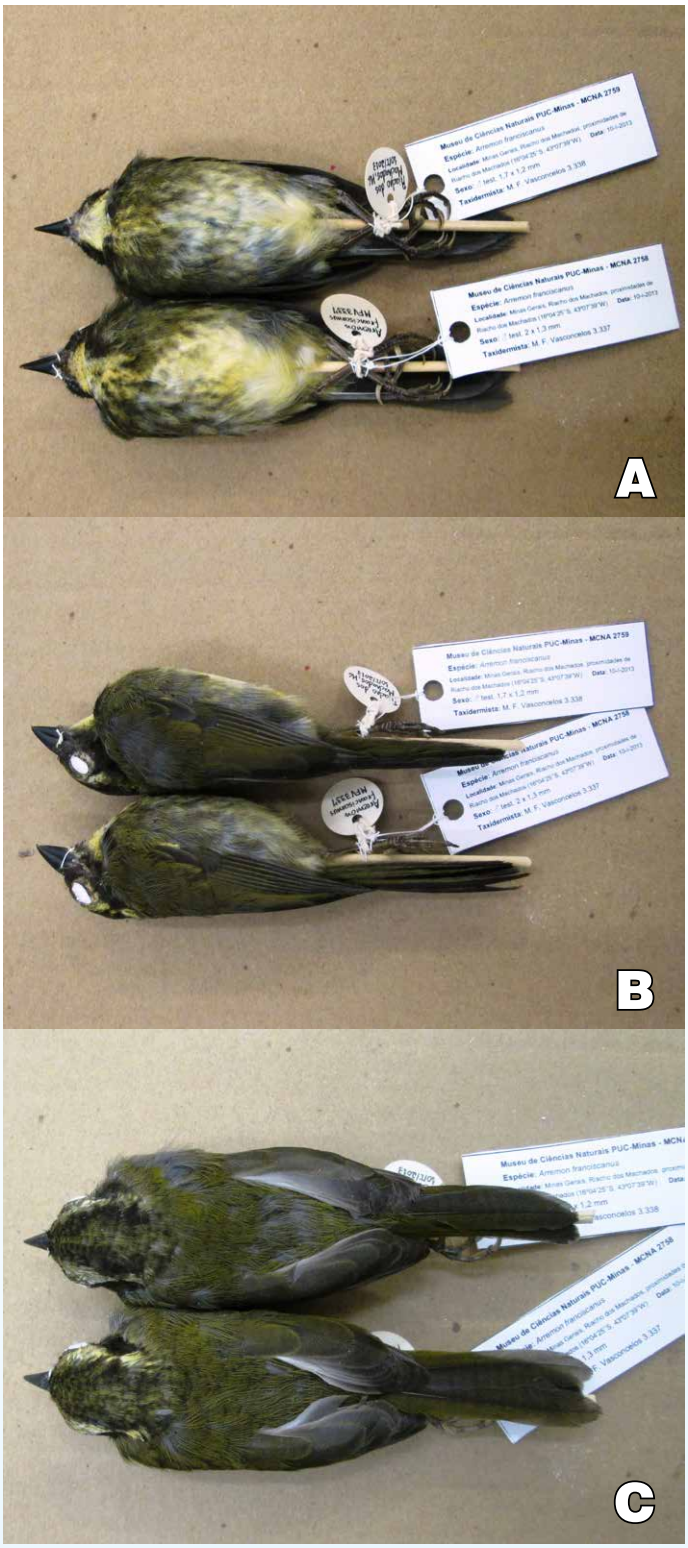

Figure 4. Juvenile males of São Francisco Sparrow *Arremon franciscanus* (MCNA-2759 [top] and MCNA-2758 [bottom]) in ventral (A), lateral (B), and dorsal (C) views. Photos: Marcelo Ferreira de Vasconcelos.

Soft-part colors

Adults of both sexes of *A. franciscanus* present upper mandible yellow with culmen black and lower mandible

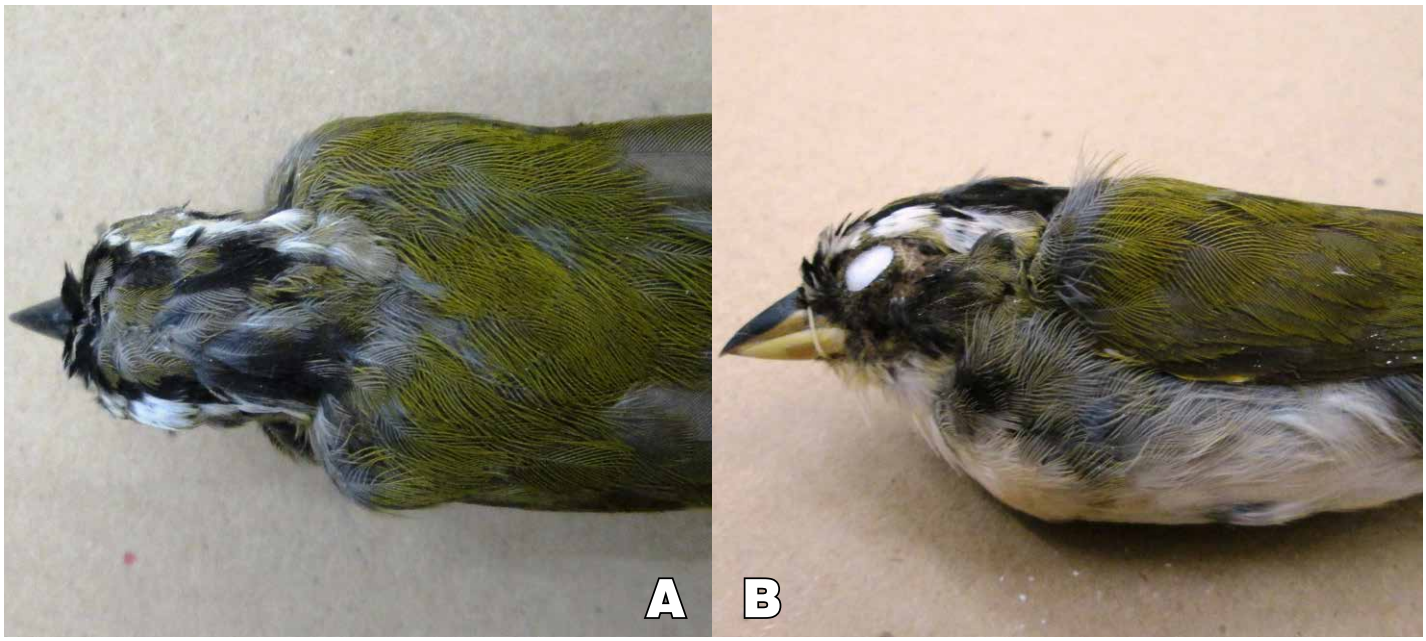

Figure 5. Subadult male of São Francisco Sparrow *Arremon franciscanus* (MCNA-1575) showing the predominantly olive pileum washed gray (A) and facial mask and inconspicuous interrupted pectoral band black suffused with olive, especially in the auriculars (B). Photos: Marcelo Ferreira de Vasconcelos.

yellow. The yellow in the beak of some males is brighter than in females, but the significance of this variation is still unknown based on the small number of analysed specimens and it is probably related to the season (breeding or not). The only subadult female present dusky yellow bill with black culmen. The upper mandible of juveniles is black and the lower mandible is also black with inconspicuous yellowish-green margins. All specimens had irises that were dark-brown. Tarsus color varies among gray, grayish-brown and pinkish-gray, but this variation was not indicative of any sex or age class.

Systematic relationships

A recent molecular phylogenetic hypothesis placed *Arremon* in the Passerellidae family, in which *A. taciturnus* and *A. semitorquatus* are sister taxa, immediately related to a second clade composed by *A. flavirostris* and *A. schlegeli*, and both clades as sister to *A. abeillei* and *A. aurantiirostris* (Klicka *et al*. 2014). However, *A. franciscanus* was not included in the analysis and its systematic placement remains unknown. As supposed by Raposo (1997), females of *A. franciscanus* are more similar to those of *A. semitorquatus* and *A. flavirostris* because they have a pectoral band that is absent in females of *A. taciturnus*. Even so, *A. franciscanus* would be more related to *A. taciturnus* and *A. semitorquatus*, since they share the black chin and the interrupted pectoral band conditions (see *A. t. nigrirostris*) absent in *A. flavirostris*. Thus, taking into account the overall morphological similarities, *A. franciscanus* was considered most similar to *A. semitorquatus* and it is likely that these two species are closely related (Raposo 1997). Nevertheless, a recent vocalization study has shown that the vocal pattern of *A. franciscanus* is more similar to the one found in *A. flavirostris* than in *A. semitorquatus* and *A. taciturnus* (Buainain 2015). Furthermore, there seem to be many cases of convergences and regressions of morphological characters in the genus *Arremon*, as they appear to be "shuffled" among different species-groups. That makes systematic inferences using plumage characters problematic. For example, the yellow bill is present in almost all species, except in *A. t. taciturnus* and *A. abeillei*, which are currently included in distinct "yellow-billed" clades. The same happens with the coloration of the back, which is gray in *A. flavirostris polionotus* and in the more distant related *A. abeillei and A. schlegeli,* but green in its conspecifics *A. flavirostris flavirostris* and *A. flavirostris dorbignii*. Similar patterns can also be observed in the extension of the pectoral band and superciliary stripes, the presence of a black chin spot, the bend of wing coloration, and in other traits. Therefore, we stress that it is still necessary to complete an adequate phylogenetic analysis, perhaps with molecular data and more representation in terms of subspecies, to determine more precisely the evolutionary relationships of *A. franciscanus*.

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Table 1. Collection data for specimens of São Francisco Sparrow, *Arremon franciscanus*, analyzed in this study. Localities are presented from north to south.

Registration number	Locality	Sex	Age	Date
DZUFMG-6135	Brejinho das Ametistas, Caetité, BA	Female (ovary 4.2 × 2.7 mm)	Adult (skull 25% pneumatised)	3 May 2008
DZUFMG-6140	Brejinho das Ametistas, Caetité, BA	Female (ovary 5.4 × 3.7 mm)	Adult (skull 100% pneumatised)	4 May 2008
DZUFMG-6141	Brejinho das Ametistas, Caetité, BA	Female (ovary 2.7 × 1.5 mm)	Subadult (skull 10% pneumatised)	4 May 2008
DZUFMG-6554	Brejinho das Ametistas, Caetité, BA	Female (ovary 6.2 × 4 mm)	Adult (skull 100% pneumatised)	21 August 2008
DZUFMG-6134	Brejinho das Ametistas, Caetité, BA	Male (testes 6.4 × 4 mm)	Subadult (skull 25% pneumatised)	3 May 2008
DZUFMG-6142	Brejinho das Ametistas, Caetité, BA	Male (testes 5.3 × 3.3 mm)	Adult (skull 100% pneumatised)	4 May 2008
DZUFMG-6569	Brejinho das Ametistas, Caetité, BA	Male (by plumage)	Adult (skull 30% pneumatised)	25 August 2008
MN-47712	Serra do Salto, Caetité, BA	Male (testes 9 × 6 mm)	Adult (by plumage)	3 February 2009
MN-39520 (paratype)	Cândido Sales, BA	Male (enlarged testes)	Adult (by plumage)	No date
MCNA-1575	Águas Vermelhas, MG	Male (testes 2.3 × 1.6 mm)	Subadult (skull 20% pneumatised)	22 February 2011
MN-43037 (holotype)	Mocambinho, Jaíba, MG	Male (testes 9 × 4 mm)	Adult (skull 100% pneumatised)	9 December 1995

Registration number	Locality	Sex	Age	Date
MN-43038 (paratype)	Mocambinho, Jaíba, MG	Male (no gonad measurements)	Adult (skull 100% pneumatised)	9 December 1995
MN-43039 (paratype)	Mocambinho, Jaíba, MG	Male (testes 5,5 × 4,5 mm)	Adult (skull 100% pneumatised)	9 December 1995
MN-43040 (paratype)	Mocambinho, Jaíba, MG	Male (testes 6 × 4 mm)	Adult (skull 100% pneumatised)	9 December 1995
DZUFMG-2480	Mocambinho, Jaíba, MG	Male (testes 1.2 × 1 mm)	Adult (skull 100% pneumatised)	19 May 1997
MCNA-2001	Riacho dos Machados, MG	Male (by plumage)	Adult (skull 100% pneumatised)	17 April 2012
MCNA-2758	Riacho dos Machados, MG	Male (testes 2 × 1.3 mm)	Juvenile (skull 10% pneumatised)	10 January 2013
MCNA-2759	Riacho dos Machados, MG	Male (testes 1.7 × 1.2 mm)	Juvenile (skull 10% pneumatised)	10 January 2013
MCNA-2760	Riacho dos Machados, MG	Male (testes 7.3 × 6 mm)	Adult (skull 100% pneumatised)	10 January 2013
MCNA-3590	Riacho dos Machados, MG	Male (testes 2.2 × 2.1 mm)	Adult (skull 100% pneumatised)	20 July 2013
MCNA-2761	Riacho dos Machados, MG	Female (ovary 6 × 3.6 mm)	Adult (skull 100% pneumatised)	10 January 2013
MCNA-3591	Riacho dos Machados, MG	Female (ovary 6.4 × 4.2 mm)	Adult (skull 100% pneumatised)	20 July 2013
DZUFMG-3382	Fazenda Imburana, Francisco Sá, MG	Male (testes 4 × 3 mm)	Adult (skull 100% pneumatised)	31 March 2002
MZUSP-76180	Campo de Avião, Francisco Sá, MG	Male (testes 6.3 × 4.7 mm)	Adult (skull 100% pneumatised)	10 October 2003

Table 2. Morphometrics (see text for details of measurements in mm) and body mass (g) of São Francisco Sparrow *Arremon franciscanus*. Values are mean ± SD, with range and *n* in parentheses.

Age and sex	Width of bill at nostrils	Height of bill at nostrils	Length of bill from nostril	Length of total culmen	Length of closed wing	Length of tarsus	Length of tail	Total length	Body mass
Adult males	5.1 ± 0.1 (4.9–5.4, 13)	7.1 ± 0.4 (6.6–8.1, 13)	10.2 ± 0.4 (9.7–11.1, 12)	15.7 ± 0.8 (14.4–17.6, 12)	71.0 ± 2.0 (67.4–73.9, 14)	22.8 ± 0.8 (21.6–24.6, 14)	64.9 ± 2.7 (61.4–70.1, 14)	159.5 ± 5.2 (150.0–167.0, 13)	24.3 ± 1.8 (21.0–27.0, 12)
Adult females	5.0 ± 0.2 (4.8–5.3, 5)	7.0 ± 0.1 (6.9–7.1, 5)	9.9 ± 0.3 (9.5–10.3, 5)	14.8 ± 0.4 (14.1–15.1, 5)	67.0 ± 1.4 (65.6–69.0, 5)	22.7 ± 0.5 (22.2–23.5, 5)	61.1 ± 1.3 (59.1–62.1, 5)	156.2 ± 2.4 (154.0–160.0, 5)	23.5 ± 0.6 (23.0–24.2, 5)
Juvenile males	5.0 ± 0.2 (4.9–5.2, 2)	6.7 ± 0.2 (6.6–6.8, 2)	8.8 (8.8, 2)	14.8 ± 0.1 (14.7–14.9, 2)	67.1 ± 1.5 (66.0–68.2, 2)	23.2 ± 0 (23.1–23.2, 2)	61.2 ± 2.7 (59.3–63.1, 2)	156.0 (156.0, 2)	24.1 ± 0.1 (24.0–24.2, 2)
Subadult males	4.9 (4.9, 2)	6.6 ± 0.1 (6.5–6.7, 2)	9.6 ± 0.1 (9.6–9.7, 2)	14.3 ± 0.1 (14.3–14.4, 2)	69.9 ± 4.6 (66.7–73.2, 2)	22.3 ± 0.2 (22.1–22.4, 2)	60.9 (1)	142.0 (1)	21.5 ± 0.7 (21.0–22.0, 2)
Subadult female	5.0 (1)	6.8 (1)	9.5 (1)	14.7 (1)	68.7 (1)	23.3 (1)	–	–	25.3 (1)